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Overstock and stock-out in Volkswagen Autoeuropa

Practices of Volkswagen Autoeuropa to deal with these concerns and their influence on operational performance

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1. Abstract

The following work is a case study of overstock and stock-out problems at Volkswagen Autoeuropa (VWAE). It introduces the supply chain of Autoeuropa and specializes then on failures connected to inventory problems. Having a successful supply chain is important in a world where products become more and more similar as it can give to companies an edge over their competitors. The case shows three practices that VWAE uses to prevent and to overcome stock problems. Information was gathered by doing interviews with different managers, by analyzing the company's key processes and by literature research related to the topics of supply chain management and flexibility in the supply chain. Three practices were further investigated: the use of alternative parts, support of the supplier and a rating system of suppliers. In the question section of this work the importance of flexibility and Supplier Relationship Management (SRM) when connected to supply chain management are explained. The described different practices are numerically analyzed and it is concluded that each practice brings both cost savings and the possibility of achieving target numbers to the company, showing the company's flexibility to react to supply chain disturbances.

Because of confidentiality reasons, persons in the case are fictionalized and numbers are wherever possible equalized to 100 in order to display true proportions.

2. Purpose of the work project

As for any production company the right management of the supply chain is imperative for success. Even though having a successful supply chain management, supply chain concerns occur daily in Volkswagen Autoeuropa (VWAE). In general, concerns can be related to:

- Inventory Management:

  The purpose of inventory management is to maintain the lowest inventory level that still allows satisfying customer demand.[1] VWAE, having varying demand, has two inventory policies: They have Just In Time (JIT) parts which are those parts that are big and it would raise inventory cost dramatically to store them because of high holding cost. Moreover those parts are provided by companies with a geographically close location. Besides, the company has parts held in stock which are those parts that come from further destinations and hence holding a certain inventory is essential to secure no stock-out for these products.

- Customer response:

  The customer response links logistics to the customer and to sales and marketing. It is mainly concerned with entering and processing orders and with customer satisfaction.[2] VWAE applies a built-to-order policy and orders are processed using an MPR and an EDI system as well as using the Volkswagen (VW) internal platform www.vwgroupsupply.com. Concerns might arise because it may not be possible to process orders promptly.

- Transportation:

  The objective is to synchronize pick-up and delivery with the customer service policy that the company holds while optimizing cost.[3] VWAE has recently

started to adapt new practices like the milkrun and direct collection in its supply chain. The reason for only recent implementation is that a company needs to know well which suppliers are key suppliers and the quantities they need from those to see whether those practices pay off.

- Warehousing:

  The objective is to minimize cost of space, labor and equipment in the warehouse.[4] VWAE holds one warehouse which is located 30 km from the production plant. Concerns in this area can arise because of overstock.

The following case focuses on inventory management and more specifically on overstock and stock-out problems that can arise because of the afore mentioned. For VWAE stock-out can occur for both, JIT and stock parts. Those concerns occur when a supplier does not deliver products in time or when products get damaged at the production plant of VWAE and they can have several causes which are explained in the case. Overstock on the other hand arises when the company has more stock than its target inventory level which is calculated as a weighted average between all the parts that are held in stock. The optimal stock level of a part is given by the overage and underage cost of a product. When knowing those cost, one can calculate the optimal service level a company should have for a certain part. This service level is defined as the probability of having the part in stock, and hence being able to "serve" the demand. The optimal service level of a part can be calculated as follows:

$$F(Q) = \frac{C_u}{C_o + C_u}$$

Where

C_o represents the cost of ordering one more unit than what the company would have ordered if demand was known

C_u represents the cost of ordering one unit less than what the company would have ordered if demand was known

$F(Q)=Prob\{Demand \leq Q\}$

Hence the order quantity that maximizes profit is the order quantity Q such that demand is less than or equal to Q with probability $C_u/(C_u+C_O)$.

Stock-out and overstock must be avoided because of the cost that they can incur. It is important for any company to know what forms part of these costs in order to calculate the balance between lost sales and holding inventory.[5]

Stock-out costs contain both internal costs like delays, wasting of labor time etc and external cost like backorder costs.

Overstock cost on the other hand are basically holding cost for having the product for longer time in inventory than needed.

Overstock or stock-out can hence have an impact on VWAE's performance. By finding sustainable solutions VWAE can gain more flexibility to react in case that the supply chain is harmed.

The case intends to show cases of overstock or stock-out and how VWAE dealt with them. It furthermore gives room for suggestions of both other best practices that the company could adopt and KPIs the company could use to measure those new best practices as well as old best practices that are still not measured.

The case can be used for courses of Operations Management and Global Supply Chain Management.

3. Case Study[A]

Introduction

John Smith sighed when he hung up the telephone. It was the second time that this happened since he became the new supply chain manager at VWAE, the Portuguese production plant of VW. The production line had stopped because they had run out of stock of part A that was located in the rear of the car. Those parts were produced in Poland. After a total machine breakdown the supply of part A was not secured anymore for the next weeks. John did not even want to think of the consequences of a production stop. It would imply special deliveries, idle workers and extra shifts. Even though the suppliers were billed for any problem where they could not deliver, any production stop would be a concern for VWAE as well. He decided to have an extra meeting with his team. They had to find a solution.

Vokswagen group and the role of Volkswagen Autoeuropa

VW was founded in 1937 and started production of its first vehicle designed by Ferdinand Porsche in 1938. In 2010 the group was the second biggest car producer worldwide and the biggest in Europe in terms of production volume. Since 2003 nearly all of its procurement volume was managed online. With a procurement volume of more than €75.4 billion and with more than 60% of the final car components coming from suppliers, a well functioning supply chain became essential to stay competitive.

[A] This case was solely prepared as the basis for class discussion. This case is not intended to serve as endorsement, source of primary data or illustrations of effective or ineffective management. This case, though based on real events is fictionalized and any resemblance to actual persons or entities is coincidental. Numbers are invented, but show the real proportions.

For the prior several years the automotive industry had been faced with a number of challenges including decreasing profit margins because of higher raw material costs and fiercer competition due to new entrants from China and India as well as decreasing customer loyalty.[6] Saving cost therefore became one of the main targets of automobile companies and flexibility in the supply chain became one of the main objectives to reduce cost.[7]

The VW group, consisting of nine brands, had more than 5,500 suppliers. Using forward sourcing and global sourcing, it had implemented two of the main best practices that guaranteed cost-savings in the supply chain. Forward sourcing integrated the suppliers from an early stage of development of a new product while the target of global sourcing was to look for the most cost-saving supplier to a company worldwide. Apart from that, VW used its online platform www.vwgroupsupply.com to manage which supplier got the final acceptance when bidding for the production of a supply part.[8]

The electronic platform of VW was launched in 2001 to facilitate worldwide communication between the concern and its suppliers[9] and most of the supplier management since then was done via the platform. As most of the car consisted of supply parts, it was important to have effective practices in the supply chain. The aforementioned global and forward sourcing along with a well introduced MRP system were only a small part of the successful supply chain. The VW concern used several quality controls to assure a well-working supply chain. First of all were all suppliers contracted by the headquarters which assured the use of global standards. Each plant could make suggestions on suppliers and rate them on a regular basis using an ABC rating system. In general, suppliers had to stand against hard criteria to be selected for

the VW group and the ABC rating measured the supplier on several dimensions. An A stood for a fulfillment of 90% or more of the VW group's criteria, a B for a fulfillment between 80% and 90% and a C meant that the rated factory of the supplier would not be contracted again for VW projects worldwide (compare app. 1). Regular audits within the supplying factories assured that process weaknesses would be discovered quickly and could be improved. As it was not an easy task for the VW group to change a supplier during the production of a certain car model it was imperative for VW to set high standards in order to minimize concerns of stock-out and overstock. Since there was no incoming inspection in the plant it was even more crucial to have reliable suppliers. A ranking of B gave a clear signal to the supplier that he had to change policies quickly if he wanted to continue working with the VW group and an improvement plan was required. Each plant held regular meetings with its key suppliers. In those meetings each supplier gave a status of the current situation and explained whether there might be a difficulty in the supply of certain parts in the following week which could result in stock-out of the respective plant.

The production then consisted of Just in Time (JIT) and inventory parts. Inventory was held within a strict inventory policy. VWAE itself did not produce for inventory. Having a make-to-order policy, each car produced was already sold.[10] This was important because each car was highly customized which meant that cars in inventory might not be sold and would then become obsolete.

VWAE, one of the most modern automobile plants in Europe, was VW's manufacturing plant in Portugal and was with an initial investment of €1,970 million the biggest foreign direct investment in Portugal. In 2007 the VW group invested another €57 million which should help the plant to gain more flexibility. The factory was located in

the Industrial Park, 30 km away from Lisbon, where also VWAE's main JIT suppliers were located that supplied the factory with the cockpit, the roof and the bumpers of the car. VWAE was ISO9001 and ISO/TS 16949 certified and promoted since its own certification also the certification of its suppliers.[11]

VWAE had a production area of 1.1 million m^2. Its products were VW Eos, VW Scirocco and the Multiple Purpose Vehicles (MPV) VW Sharan and Seat Alhambra. It had more than 4,400 supply parts coming from 671 suppliers and representing more than 95% of the final car when compared to the in-house produced parts.[12] In 2010 the company had a production volume of 101,284 cars and a sales volume of €1,646 million which showed an increase of 17.7% and 25.9% respectively when compared to 2009. Most of the cars produced in the factory were for export; in 2010 only 1.4% was produced for the domestic market. The total impact on the country's gross domestic product (GDP) was 1%. If compared to the 7% of the whole car industry[13], VWAE already accounted for more than 14% of the total industry impact on the GDP. In its segment VWAE Portugal had no competitors. The company produced 920 minutes per day.

Since its foundation VWAE adapted different best practices in the supply chain to avoid overstock and stock-out in their plants.

Description of the industry

In 2005 the top six companies of the car producing industry, one of them being VW, accounted for more than 50% of the global sales. Being a highly competitive industry where lower prices could be a competitive advantage, main car manufacturers tried to focus their efforts on reducing cost and improving production efficiency. With rising

raw material prices in 2004 automakers moreover faced sinking profits. As a result labor forces were reduced and work was partly outsourced.[14] But still in 2010 the car industry was the biggest engine of employment for the EU providing more than 2 million jobs in the car manufacturing industry and around 10 million jobs in supplying industries. Europe, with exports accounting for more than €70 billion per year, was the biggest producer of vehicles worldwide and encompassed 250 plants in 18 countries. The European car industry had 15 major players.[15] VW, with sales of €89.56 billion, was the biggest car producer of the continent.[16]

In 2008 market demand fell by 7.8% and only five European countries had new car growth, Portugal being among them with a growth of 5.7%.[17] However, in the first three quarters of 2010 the total car production in the EU had risen again by 15% compared to the same period of the year before. Portugal was an important automobile producer and had an annual production of 227,325 units in 2006. The country had five car manufacturing plants: VW, Opel, Toyota, Peugeot Citroen and Mitsubishi trucks. Major supplier plants were mostly clustered around the main customer plant.[18]

Supply Chain of VW Autoeuropa[B]

VWAE received the exact orders from the central six to eight weeks before the cars had to be delivered (app. 2). Suppliers could see those orders as well. The JIT suppliers however just saw the quantities they had to produce of each model. The final production order was given to them in the week of the production by VWAE or sometimes only during the day of the production. As the suppliers produced JIT themselves, VWAE

[B] The description of the supply chain is simplified as a more extensive explanation would go beyond the scope of this work

adapted its policies of JIT to the policies of its suppliers. Moreover, JIT was adapted for parts where warehouse cost would be too high and for parts that were highly customized in each car.

VWAE's JIT suppliers were either in the industrial park itself or in a very short distance of VWAE. This was very important because VWAE's JIT parts were supplied in sequence to arrive exactly at the moment when they were needed in the production line. Other parts were kept in inventory where a goal of 100[19] days of inventory turnover was set for the plant. Most of the customized parts were JIT parts and they arrived exactly at the time when they had to be installed in the production line (app. 5) The other parts that were held in inventory were taken from the warehouse to the supermarket (see production plan), a closer place to the production line, so that they had a closer location to the final production when needed. After the cars were finished, each car was tested and then delivered to the VW logistics group which would then deliver it to its final destination.

As one can see from that the supply chain was highly sensitive to stock-outs because of two factors: One factor was the short inventory turnover target for those parts that were stored. Another factor was that the JIT parts were delivered directly to the production line. Missing parts could make the whole production line stop. This was even more serious because the production line for all models was integrated into one single line which was only separated in the end for the assembly of the steering wheel and the seats. Hence, a missing part for one model would stop the production for all models as the models were produced in sequence. A production was with €40,000 for the first hour and with €80,000 for the second hour very costly (compare app. 3). [20] In a similar

way was the supply chain sensitive to overstock. This would raise the inventory turnover rate which could be mirrored in the plant's running costs of procurement.

Moreover the company could miss the targets of KPIs (compare app. 4) affected by stock problems. Missing targets by too much could mean that when VWAE applied for the production of a new model they would not get approval for being the producer of that model.

Both, stock-out and overstock happened on a daily basis, but VWAE and the VW group had delivered several tools to face those concerns.

Stock-out concerns of VWAE

Mr. Smith was well aware of the implications of a stock-out for the supply chain of VWAE. And he knew that a solution had to be found quickly. The supply chain was an integral part for the company's success. In a world where products got more and more similar a well working supply chain could bring the competitive advantage. In this context well working meant that there would have to be enough flexibility to react to stock-out or overstock concerns[C]. If there was an incident in some upstream parts of the supply chain, VWAE would need to have mechanisms to react to those failures. The company adopted many best practices that would help facing the problem of stock-out and overstock. The interruption of the production due to stock-out was one of these problems and it was even more serious because all models of the Portuguese plant were produced in the same line until they were separated in a late stage for final installations.

[C]: Stock-out cost mostly imply the cost for the stop of the production. Hence, for each product described, the necessary cost of the production stop for installing 1 product was calculated and equalized to the underage cost. As the company has an average service level is an average of 99.7%, overage cost could then be calculated.

The stop of one model would have implications on the production of all the models. With stock-out cost of €3,870 (compare app. 3) per part A the lack of one part A could be costly for the company. Knowing that for each non-installed part A, the production would stop for about 3 minutes and that daily 75 cars were affected, John brainstormed with his team different solutions to overcome the shortage of part A. They thought of one particular solution that they had applied in a similar incident shortly after John had started in his position. In that time, part B could not be delivered due to a problem of their supplier. Part B was a JIT part and was installed in an early stage of the production. As the sensors in the production line would only continue production if the car had its complete length, production interrupted when the company ran out of those supply parts. If a JIT supplier could not deliver a part because of a constraint, VWAE would be notified 1 to 24 hours before they would actually have to install the parts. This meant that the company had little time to react if they were going to be missing JIT parts. They therefore decided to use alternative parts in order to be able to continue production. Those alternative parts were used whenever possible and necessary if a supplier could not deliver conform parts. An alternative part was a part developed by VWAE especially for situations where they had to overcome stock-out issues. In order to continue the production flow, the company, whenever possible and necessary, used those alternative parts and installed them so that the car could proceed in the production line. This was necessary because sensors throughout the production would read if the part was installed and if this was not the case the production would stop immediately. Once the car was completely finished and the conform part was available, the alternative part was uninstalled and the conform part was installed. Suppliers had to deliver those alternative parts whenever they could not deliver conform parts. The cars

with alternative parts would therefore proceed through the whole production and all the quality tests would be done on it and it would then be stored in the car park until the conform parts were delivered. In the case of part A, the alternative part was necessary to proceed the car through the electrical test and finish all the other tests on it, hence not having part A would make it impossible to run the car through the last 120 minutes of the final production. After receiving the conform part, the company would only need to perform the electrical test, which took about 20 minutes, again and the car could be sold. The time that it had to be stored in the car park was depending on the expected delivery delay of the supplier between some hours and several weeks. On average it deferred the final delivery to the VW logistics group by three days. In case of a supply delay VWAE would therefore ask the supplier to deliver the alternative parts and install them to continue the production flow. VWAE itself did not hold any stock of alternative parts because as VW acted according to the principle “who has the problem, has to pay”, VWAE did not want to raise its warehouse cost by holding additional alternative parts. Therefore, it was the suppliers’ responsibility to have these parts. Even though the installation of an alternative part would still mean more work because of its removal and the new installation of the real part and the additional running of some of the tests (compare solution) it would also save a lot of cost because production would continue. John Smith decided that there was no alternative to the use of alternative parts. Part A was a product that VWAE held in stock, but the stock was only for some days. Their supplier however was able to produce an alternative part and send those until the machine breakdown would be solved which was expected to take three weeks.

Overstock concerns

One of Mr. Smith's department's KPIs was the inventory turnover. The VW group had established a rate of 100[21] days which was based on a benchmarking amongst its factories.[D]. Most of the times it was possible for the company to stick to this rate or even be below it. However, he remembered a specific concern that they had with one supplier. This supplier would repeatedly deliver material before the actual delivery date. As a consequence the inventory turnover rate would rise because of overstock and with it warehouse costs. The plant had with the ABC ratings one measurement at hand that could help them to put some pressure on their suppliers. As an additional measure to increase pressure, John Smith introduced the Lemon Award which would be awarded to the worst supplier of the month. He introduced it because of a steady surplus of product C, of which the inventory turnover rate had risen by 1.57%. Since taking this measurement, dissatisfaction with supplying companies had decreased noticeably.

The newest challenge: Demand forecasts and suppliers' capacity constraints

Production numbers for each car model were anticipated by the marketing team based on market research. Those numbers were then communicated to suppliers which would already know whether they were able to produce the expected number of units or not. The numbers would then after production start be adjusted to real demand. Concerns arose when those forecasted numbers changed significantly. Some suppliers would then have capacity constraints which would make it hard for them to produce the expected

[D] $Inventory\ Turnover = \frac{Piece\ price * Quantity}{Cost\ for\ material\ for\ each\ model}$

number of units. The current situation that John was going to discuss was about one supplier that delivered part D. Call-off orders had to be raised by 5% for more than six months now and the supplier had given signals that it could not keep up with extra-production due to capacity constraints if those orders would raise by more. John had to decide between two possibilities: either he would not accept the extra-orders from the headquarters anymore and hence the supplier would not have any capacity concerns or he would accept the additional orders and then pass the problem on to the supplier. If he decided for the second solution the supplier would need support from VW to expand capacity by introducing an extra-shift to produce the newly requested number which was 75[22] parts more. Otherwise the production would stop for 2 minutes per car if the capacity was not raised and most probably VWAE would get the order from VW in any case (Calculations for this solution are below).

4. Discussion Questions

A well functioning supply chain is an integral part of the success for VWAE

VWAE has a supply chain that is very sensitive to any kind of disturbance. Any missed delivery or delivery that arrives to early at the plant's warehouse can result in stock-out or overstock respectively. VWAE has those parts in inventory were they must protect themselves from delays or long distances of their suppliers[23]. On the other hand, overstock can influence the company in a negative way as it raises the inventory turnover. Disturbances that cause inventory problems can occur not only in tier 1, but also in tier 2 and 3 suppliers. A tier 1 supplier is a supplier that directly delivers to VWAE. A tier 2 and 3 supplier on the other hand would be a supplier that does not

supply VWAE directly, but it delivers to one of VWAE's suppliers. If anything goes wrong, VWAE will be the supply chain member who suffers most because it is the last element before the car is delivered to the customer. Hence, any problem will result in a problem for the plant. Even though VWAE may not have direct competitors in Portugal it has so in the world. As most of its products are sold abroad it is crucial for the plant to stay competitive on a worldwide scale. A well working supply chain must provide enough flexibility to a company to react to overstock and stock-out concerns. These concerns need to be avoided because of two things: 1) stock out cost in case that an order cannot be delivered on time and must therefore be delivered later and 2) holding cost if there is excess inventory[24] which is mirrored by their inventory turnover rate. In app. 3 one can see the overage and underage cost that the company faces for different products. One can conclude from this, that the company must be very careful to neither have too few units as it is very costly nor to hold too much excess inventory as this keeps holding cost too high.

As one knows from current research, Supply Chain Management correlates positively with market performance which then again correlates positively with financial performance.[25] It is furthermore known that flexibility is important in a manufacturing system and it will have an influence on financial performance.[26] The plant's goal is to become more flexible. In operations management one refers to operational flexibility. It shows the ability of a company to 1) adapt quickly to changes in demand and 2) adapt to disruptions in the supply chain by adapting its own or suppliers' processes.[27] For VWAE, this flexibility can be reached by incorporating improvements in its current supply chain management and by monitoring these improvements on a regular basis.

The importance of managing the relationships with VWAE's suppliers in order to prevent overstocking and stock-out

VWAE highly depends on its suppliers. As mentioned in the case, more than 95% of the cars' final parts are supply parts. A concern that a supplier has will hence automatically have an impact on VWAE. Even a concern of a tier 2 or tier 3 supplier can still influence the company. Considering that suppliers come from all over the world and bearing in mind that there are many JIT suppliers, one can assume that the supply chain of VWAE is highly sensitive because many different factors, both external and internal ones, can affect it. Even if VWAE holds stock from those suppliers that are further away from the plant, concerns can arise because of the inventory turnover threshold that the company has set which can be seen when looking at the example of the alternative part A from Poland. As VWAE does not produce for stock, but builds to orders, an inventory failure might then have an impact on the end-costumer, the consumer himself. Given that VWAE delivers most of its products not inside Portugal but to other countries all over the world any disturbance that results in an extra delivery can be very expensive for the plant and might have a strong impact on the company's KPIs and on its running costs of procurement.

Supplier Relationship Management (SRM) is therefore a key practice for the company. SRM is defined by cooperation between the OEM and suppliers in order to reduce cost and raise quality with the goal of improving flows between OEM and suppliers.[28] Should the supplier not be competent enough, buying firms may face concerns such as inferior quality levels. However, a firm that uses supplier evaluation and measures its suppliers' performances can prevent or limit those concerns.[29] As explained in the case, VWAE focuses strongly on the way it works with its suppliers which is due to the fact

that the company works under VW standards. The headquarters of VW selects all the suppliers and it only selects those suppliers that match VW standards (app. 1). This means that quality for example must be already controlled by the supplier so that a further incoming control by the plant is not necessary. Controlling their suppliers means that any concern is tracked down and the plant might even take action if there is a concern with a tier 2 or tier 3 etc. supplier. The company therefore is in accordance with the main objective of SRM because collaboration, as research shows, may improve performance in areas like inventory reduction and it may therewith prevent inventory problems.[30]

Best practices that VWAE uses to prevent stock-out and overstock and suggestions for new best practices

VWAE has several practices to prevent both stock-out and overstock of their supply parts. First considering the stock-out the plant can face the following problems: Stock-out of parts that are kept in inventory and stock-out of JIT parts which are however treated with similar methods. Implications on their supply chain are that VWAE must interrupt its production if no feasible solution is found. This can then result in late delivery or extra deliveries which in either way is costly. VWAE introduced several practices to deal with stock-out:

- Alternative parts which allows the plant the continuation of its production flow
- Support of suppliers in case of capacity constraints which can prevent future stock-outs

Secondly, regarding the overstock, the company has two tools that are interconnected:

- An ABC system that classifies their suppliers according to their reliability which was implemented by the VW group
- The "Lemon Award" which is awarded to the worst supplier of the month and serves as a warning in order to improve punctuality of deliveries

The plant could introduce additional measures: As can be seen in the case, some suppliers have concerns of reaching call-off numbers when they differ a lot from the marketing forecasts. VW could choose those suppliers for VWAE that have surge capacity which is especially important for companies like VW as they have long-term contracts with suppliers and hence forecasts can never be that accurate.[31] When finalizing the contract, the supplier could give an option to VWAE to use more of the supplier's capacity in case it is needed.[32]

Another practice that the plant could introduce is Vendor Managed Inventory (VMI). In this model the supplier can access the inventory level of the OEM and can replenish the parts needed without that the company has to order them.[33] This practice helps to prevent stock-outs by effectively processing orders and deliveries.[34]

To measure current and future practices the company has the following KPIs:

- For the concern of overstock the company uses inventory turnover rate which is measured as follows:

$$Inventory\ Turnover\ rate = \frac{Material\ cost\ per\ unit * Quantity}{Weighted\ cost\ of\ material\ for\ each\ model}$$

- Stock-out of parts results in a production stop, so the used KPIs are:
  - Uptime of production line
  - Parts missing at line

Other KPIs that could be used are:

- Missed deliveries per thousand
- Number of production stops

The calculations of cost and KPIs are explained using the example of alternative part A:

	No practice	Practice
Additional cost: occur because the product is not finished in the normal production time	Number of parts not produced * time of line stoppage * cost of line stoppage per minute: 40,000*1+165/60*80,000	Time of rework * hourly cost for rework * cars affected + fixed cost (20/60)*92*75+300
Cycle Time	Actual cycle time per car + 60s*time of daily production*number of production days in car park*average number of cars in car park+time of rework*60 s/number of cars affected (100+60*920*15*(75/2)+120*60)/75	Actual cycle time per car + 60s*time of daily production*number of production days in car park*average number of cars in car park+time of rework*60 s/number of cars affected (100+60*920*15*(75/2)+120*60)/75
Uptime	(920-time of line stoppage)/Total possible uptime	(920-time of line stoppage)/Total possible uptime
Flow Time	Time of production stop + time of rework + Production time per day * number of days stored in car park +first production run 3/60+120/60+((920*15)/60)+100	Time of rework + Production time per day * number of days stored in car park + first production run 20/60+((920*15/60)+100
Parts availability	(Number of cars produced per day-number of missing parts)/Number of cars scheduled per day	Number of cars produced per day/Number of cars scheduled per day
Inventory Turnover[E]	(Material cost per unit*quantity) / Weighted cost of material for each model	As there are a lot of materials no example could be provided by the company

1

The following table shows the improvement that each measure has on the different KPIs (all numbers, except for costs when there is no disturbance are dummy numbers that were equalized to 100):

[E] Example is for Lemon Award as it is not applicable for the part A

		No disturbance with dummy numbers	No improvement cameras	Alternative part	Improvement altern. part	No financial support	Financial support	Improvement financial supp.	No award	Award	Improvement award
Additional cost		-	260,000.00 €	2,600.00 €	99.0%	120,000.00 €	0.00 €	120%	1.57 €	no cost	1.57%
Production KPIs											
Cycle Time in terms of reworked car	min/car	1.67	7005.02	6905.02	1.4%	4,745.0	4,610.0	2.8%	n/a	n/a	n/a
Uptime of line	%	100	75.5%	100	24.5%	83.69%	100	16.31%	n/a	n/a	n/a
Flow time of one unit	h	100	7830	7775.19	0.7%	5297.00	5222.84	1.4%	n/a	n/a	n/a
Inventory KPIs											
Parts availability	%	100	-12%	100.0	12.0%	-12%	100	12.0%	> 100	-0.03%	-0.03%
Inventory turnover rate	days	100	n/a	n/a	n/a	n/a	n/a	n/a	101.6	100	1.57%

2 (Remark: Financial support is done by VW and hence no cost occur to VWAE)

One can see from the above table that:

- Additional cost are higher than underage cost*piece number because the underage cost were calculated as a weighted average for all the parts to give them a comparable base. It has to be always distinguished who is responsible for the stock-out/overstock problem in order to know who has to pay those cost.
- Each practice in itself brings advantages to VWAE. The decision which practice to apply, is always dependent on the situation. A direct comparison for production KPIs is not possible as those depend on time and not only on quantity. Moreover it depends on where in the production the part is installed and therefore which tests have to be done again.

Conclusion

VWAE has developed effective practices to avoid overstock and to face stock-out. Those practices bring both cost savings to the plant as well as the possibility to stick to their target KPIs. Operational flexibility because of different practices that the company can apply is a key to their success. The company applies best practices all over their

supply chain, benefiting from VW's long experience. Moreover, one can see that VWAE learns from failures to improve their supply chain.

Other supply chain practices, also related to topic different than inventory management may be of interest for future studies of the company, but would go beyond the scope of this work.